MODULAR INFRARED IRRADIATION APPARATUS AND ITS CORRESPONDING MONITORING DEVICES

FIELD OF THE INVENTION

The present invention refers to a modular infrared irradiation apparatus which employs combustion gas and its respective monitoring devices. Particularly, the apparatus of the present invention is direcetd to thermal transfer operations for provide quick and efficient thermal energy transfers at high rates as in industrial drying operations of paper making and cellulose industries. The irradiation apparatus comprises automation means for control the starting and all steps of the procedure which is performed by such equipment and permits multiple industrial applications.

BACKGROUND OF THE INVENTION

Technicians of the art, particularly those skilled in the continous fibrous products manufacturing processes, know that a drying step (or a set drying steps distributed along the process) is a necessary step for drying coating or impregnating substances added to the product.

Known drying techniques employ heat transfer by direct contact between the heat receiver and the planar and/or cylindrical heat source or by means of hot air blowing.

The Infrared (IR) drying technique is the most preferred because the direct contact step for heat transfer is avoided. Thus, this embodiment normally employed for complementary drying applications in the traditional drying steps of the art.

For each konwn different drying step, the desired result, e.g., substrate features, and surface and phisical properties, may differ. Therefore, in view of the above, a refined techinique, derived from known embodiments, which is complemented by IR drying step is seen as the best result maker.

Recently, the use of an IR drying process has been seen as the best alternative because such techinique is suited to several industrial applications and for provide solutions for old problems of the art.

The IR technique has particular features and such features make the difference when applied to known heat irradiation apparatus of the art. The IR

generation techniques are basically distinguished in the temperature average and in the frequence range of the irradiating element.

In the heat irradiation apparatus production, the selection of building materials determines the IR emission ability of such apparatus in some ranges of frequence, i.e., metallic irradiation elements generate long and medium waves. Ceramic irradiation elements at high temperatures generate short and medium waves. Generally, short waves have best penetration features in substrates in relation to long waves, and it permits that a substrate be dried without direct contact and avoinding damage to the dried substrate surface.

The eletromagnetic energy produced at IR frequence bands, if correctly set, will be absorved by substrate in such manner that the material will change, firstly in its initial state by absorbing heat and modifying its temperature. For volatile substances like water, the absorbed heat permits the chance of phisical state, from liquid to vapor, and thus the drying step occurs by evaporating all volatile mass contained in the substrate.

The amount of water to be evaporated from the substrate is a particular feature of the product and depends on the manfacturing route and the final application of such product. Therefore the intensity of thermal energy in each case is to be particularly determined.

IR use as a final controller of remaining volatiles in the substrate, e.g., the substrate humidity, is an alternative that depends of the irradiation element. If the element is able (or not) to change the heat emission power the process is able to dry the substract at the desired level.

Several types of irradiation models as mentioned above are known in the art. Most of them comprise a metallic frame which enclose irradiation elements into metal housings, such elements are installed side by side transversally or alongside of the process direction. The irradiation elements are positioned near to the substrate path and at least one plenum air and/or air/combustible gas mixture distributor is provided.

Irradiation elements are positioned at a minimal distance from the substrate path in order to obtain a maximum of heat transfer efficiency and avoid unnecessary substrate distortions, e.g, cause wet bands in the substrate

due to the temperature differences of the housings in relation to the irradiation elements.

Most of equipment known in the art has such minimal distance limited by the housings. If they are closely positioned, "heat shadows" are created and it causes wet bands in the substrate. A good housing positioning is necessary for avoid such shadows. By other hand, the necessary positioning reduces the equipment radiation ability and creates an air/combustion gas stream which makes the substrate drying difficult. Thus for avoid this problem, additional heat equipment is provided in order to keep a good global efficiency.

Other problems related to combustion gas mixture quality may occur. The systems of the art generally employ a not standard combustible gas mixture composition. Such differences can alter the burning stoichiometry at the irradiation elements. So, the flame can return to the inner part of the equipment at the plenum zone or at the gas injection tips and cause explosions and the process is to be interrupted for repairs for long term.

Another problem of the art is the employment of several feeding heat recovery ducts. Ducts occupy a considerable space in the production plant and it reduces a best employment of the plant space and makes a new equipment installation dificult.

Some recent techniques employ irradiation elements made of continous refractory ceramic plates as a radiation emitter. Such plates are designed for cover all width of the process and are longitudinally positioned at one or more sections. Such arrangement comprises a limitation when the process is to be fitted for other ends.

Such models presently satisfy IR irradiation quality and operation maintenace necessities, but some problems are still found:

- Framed housings provide cold zones (shadows) and a bad heat distribution, thus the irradiation element is to be positioned farer and the global efficiency is reduced;
- The power modulation is necessary in some cases; therefore IR emission bands are moved to large waves region (Planck Law for Black Bodies). This changes reduces the penetration feature of IR rays, because the way of energy

is absorbed depends on the length of the wave emitted from the emission element and it causes temperature gradient differences in the substrate, the evaporation is not effected and the substrate surface is burned. Depending on the technique an wave modulation is not possible;

- Equipments found in the art are not suited for permit sample collection from an open chamber and the residual oxygen content after the combustion is not detected.

- Even all safety steps have been taken, all equipment of the art are potentially dangerous and an explosion hazard is possible. Irradiation elements manufacturers of the art consider this possibility hard to occur, thus the design of such irradiation elements did not involve safety care.

Industries of the art need safe and low maintenance equipment for reduce the interruption time for repairs.

SUMARY OF THE INVENTION

According to the above discussed and in view of the above mentioned problems, the present invention provides a modular IR irradiation apparatus which employs combustion gas and its respective integrating devices for automatically control the air/gas mixture, for sequencing the process starting, for interlocking the equipment and the corresponding process. Some modifications in the irradiation modules have been done in order to eliminate shadow zones and to enhance gas flowability; such improvements are achieved by means of a fibrous ceramic. The fibrou ceramic have flexible pores through which the air/gas mixture flows and after the air/gas mixture emerges from an escape surface an ignition means is driven and a fire line provided and kept stable over the ceramic escape surface which acts as IR irradiation element at high frequency bands.

This preferred embodiment permits a safe operation, because the flexible fibrous ceramic does not resist to pressure, causing minimal intensity explosions and provides soft fragments when exploded. The modular design permits multiple arrangements being fitted to any drying processes, enhances the continous irradiation element operation.

All the above objectives are achieved acorrding to the following steps:

- Refractory flexible irradiation module comprising stopping means which are high temperature resistant and avoid shadow zones and side losses of heat at the burning zone in the ceramic surface;
- Employment of refractory flexible ceramic plates having flexible pores which permit air/gas modulation, the flexible pores permit define the path of the air/gas mixture through the ceramic plate. When the flow pressure of mixture is reduced, part of the pore automatically close and the combustible mixture is coducted to the surface where the hot fibers are placed. The fibres keep the combustion active at the surface, multplying IR heating effects. Ceramic plates of the art tend to “swallow” the flame causing an inner burning and reducing the efficiency of the process and/or loss of the control of the flame and equipment explosion.
- Sensors and measuring means are provided for monitoring all steps: ***Thermal sensor***- safety device applied in the lower face of each flexible fibrous ceramic module, more particularly fixed in the support screen of the ceramic plate and extending to median line of such plate, for monitoring a possible heat flow inversion due to external factors which cause the “flame swallowing”. For example, a heat reflection means positioned in front of the irradiation element in order to return IR energy back to the irradiation element and creating an ressonance effect for store heat in the irradiation element and make the flow inversion. This device avoid misemployment problems by blocking the irradiation element. This provides an extended work life of the ceramic plate. ***Oxygen measuring means*** – Continous measuring based on Zirconinum oxide. This device collects combustion gases over the burning surface in at least one module of refractory ceramic, for continous analysis ends, permitting a flame optimization e an after buring residual oxygen controlling. Such sensor is connected to a LPC (Logical Program Controller) of the monitoring, interlocking and alarming system which is driven when the level of oxygen does not match with the standard value. ***Ultraviolet (UV) Flame detector*** - It is applied in the external face of the metallic frame, more particularly, near to the combustible gas inlet, for flame detection, i.e., for combustion detection in the ceramic modules. The flexible ceramic concentrates the burning in its surface, the IR

generation occurs basically in the short waves range, including some residue at the begining of the UV spectrum which is identified by the UV detector. The UV detector is assembled as an cathode anode discharge vessel, known in the art, inserted in a housing or specially designed device for support severe operation conditions. The housing have a cylindrical shape made of metallic material provided with a lower hole and channels for better air circulation. Refrigeration air flows from refrigeration ribs and also from the ceramic discharging tube of the receptacle body of the sensor, keeping the inner pressure positive and external particulate material entrance is avoided (the equipment can use two UV flame detector); ***Bed*** – all flexible refractory ceramic modules and the first and the second plenum distribution means are positioned in the bed which is made of metallic plates having two handles and two mirrors and botton caps and couterventing strips. Between the handles and the bottom caps a safety system is provided for permit an easy opening of the caps for maintenance or for avoid bed expanding in case of explosion. The locking system permits determine the effects of an explosion.

APPLICATIONS AND ADVANTAGES

Several advantages are achieved by means the present invention. The novel modular IR irradiation means and its eletronic devices permit a better control during the operation and an enhanced global efficiency for thermal energy.

Other advantages are as follows:

- Flexible ceramic modules of the present invention permit uniform IR emission in all burning zone, avoiding shadow zones without irradiation;
- The absence of shadow zones permits that the irradiation surface be placed near to the substrate avoiding losses caused by air/gas streams and providing a collimation cavity for IR emission for avoid radiation scattering.
- Ceramic plates stopping in the irradiation modules comprise other feature of this invention, since it meets thermal-phisical requirements and avoid energy dispersion over the limits of burning zone edges.
- LPC can be programmed for logoff some modules when other are still active and meet substrate width variations requirements.

- The fiber web has some anisotropic free grade related to a particular moviment. When the gas passage is forced through the flexible ceramic, other pores are forced to open avoiding pore saturation, making the pores equivalent in relation to the conduction ability of the mixture. The average pore diameter is automatically adjusted for keep balance between the pores. This permits a gas volume and the power level modulation and keep the discharge rate controlled and fitted to the minimum limit.

- The oxygen measuring means application makes possible the residual smoke collection after the burning for continous monitoring of the residual oxygen and this system can detect failure in the combustible gas feeding. Other feature of such means is that it is able to keep a high burning efficiency and keep the previous defined stoichiometry for obtain the desired temperature and IR band results.

- Two retangular plenum employment as mechanical support of the modules permits the gas mixture feeding in the modules by means modular valves or blocking valves, when modifications and/or improvements are necessary.

- The metallic frame building having inner pressure rate and overpressure alleviating means, meets the safety requirements as the explosionproof equipment, providing a safe operation for workers and equipment.

DESCRIPTION OF THE DRAWINGS

The present inventio is best defined, but not limited to, according to the drawings as follows:

Figure 1 is a perspective view of the modular heat irradiation element provided with some irradiation modules in ready to use position and one module in exploded view;

Figure 2 is cross sectional view of the IR irradiation element of the present invention;

Figure 3 is exploded perspective view of a irradiation module, illustrating all its components;

Figure 4 is a sectional view of an oversized detail of the stopping means in the ceramic plate;

Figures 5 and 6, illustrate, respectively, side and sectional views of the irradiation module;

Figure 7 is a perspective view of part the bed and primary and secondary plenum distribution ducts;

Figure 8 illustrates the entire bed with more details, in exploded perspective, showing the positioning of the oxygen measuring means and flame UV detectors;

Figure 9 is a cross sectional view of the bed, showing the mounting system with safety device for alleviating the explosion;

Figure 10, is an oxygen measuring means, in a more detailed perspective view;

Figure 11 illustrates the oxygen measuring means mounted on the IR modular irradiation element;

Figure 12 is an exploded perspective view of the UV sensor bulbs support housing; and

Figure 13 is sectional view of the UV flame detector of the invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring to the Figures, the present invention refers to a **MODULAR INFRARED IRRADIATION APPARATUS AND ITS CORRESPONDING MONITORING DEVICES**, the modular heat irradiation apparatus (1) is directed to heat transfer operation involving elevated rates of heat to be contoinously traferred to a receiving substrate, e.g., industrial drying process of fibrous products as paper or cellulose (L) (Figure 2).

According to the present invention and Figures 1 and 2, the modular heat irradiation apparatus basically comprises a metallic frame or bed (2) which is designed for receive a number of irradiation modules (7), according to process width and in such manner to receiver distribution and support ducts, priamary plenum (3p), secondary plenum (3s) which possesses gas/ar (G) mixture feeding outlets (3a) to the modules (7).

The employment of two plena having rectangular shape (3p and 3s) serve as mechanic support fo the modules (7) in order to position them in such manner to permit the gas/air mixture (G) feeding in the modules (7) by means a

modulation/blocking valve (VL) coupled to the primary plenum (3p) or blocking free directly coupled to the secondary plenum (3s). The module presents an unique mixture (G) inlet (4) whic can be positioned aligned to the primary plenum (7v) or secondary plenum (7d), depending on the final application which can be defined by turning the module 180° and by opening passageway (3a) of the primary plenum (3p).

Such procedure can be accomplished even after the original assembling be concluded when a modification is necessary or when powe control is to be installed.

Plena (3p, 3s) are fed,firstly by the primary (3p) employing at least one side duct (G), which is further used by the secondary (3s) by means of an inner joint (JR) which is optionally and restricting means (Figure 7).

The bed (2) is made of two mirror joining (LI/LC) having lower laterals (LI) and axle type fixing supports (4) (Figure 1) which are fixed to the processes by means of locking bearings (M), permitting adjsutment of the equipment angle at the moment of the installation in relation to substrate flow direction (L).

Also, the bed has the upper side (LS) comprising lateral channels for alleviating thermal dilatation (AD) and resist to temperature variations between the upper edge and the lower edge and receiving refractory material (MR) to the irradiated IR, in order to define one irradiation cavity(CR), joined the frontal face, which is provided with irradiation modules (7). Such modules (7) are trasnversally positioned to the longitudinal axle of the bed (2) and arranged side by side in order to define a regular planar surface. The bed is further closed by metallic caps (6) which description will be provided after.

The mirror (EI) of the bed (2) (Figure 1) is provided with sealing air inlet duct (AS) for keep the inner cavity of the equipment pressurized and refrigerated; such air inlet has an independent feeding and is directed to avoid entrance and storing not desired materials and gases in the cavity, protecting the frame against gas losses. The pressurized air is directed to UV system refrigeration and venturi system, both detailed in the present appliation.

Irradiating modules (7) can be made in variable dimensions and width, and according to Figures 3,4,5 and 6 each one of the irradiation modules(7) is

made of metallic material base receiver(8), containing a feeding hole (9), positioned and not centrallized in relation to the surface of such base, for aligning with other plenum support (3p/3s) at the moment of the mounting, just inversing the module according to the plenum. The mounting at the side of the plenum (3p or 3s) is achieved employing a stopping ring (11) fitted to the feeding hole (9), which ring permits a good positioning of the module when the fixation occurs over the distribution plena (3p, 3s) and each module (7) is fixed in the plena by screws restraining pins (P).

The base (8) receives at its free edge, a screen (12) containing holes (12a) having suitable dimensions and shapes, in the lower face of the screen (12) are fixed at least two sets of sensors of thermal flow (14) interconnected by the electronic circuit (13); such sensors extend over the screen to deep contact the penetration layer of the ceramic (15) where the sensors are fixed thereto. The sensors are interconnected to an electronic device (14a), which is connected to the LPC central, not shown.

At the upper face of the screen (12) is positioned a porous flexible refractory ceramic plate (15), in which median part, under the central line (Y) (Figure 6), the thermal flow sensors (14) are kept positioned. The housing deep is determined at moment of the mounting.

Each refractory flexible ceramic plate (15) (Figure 4) is made of sealing means (S) which are high temperature resistant and arranged in thin ceramic housings (16) and placed at the side faces of the ceramic plate by means of a high temperature resistant elastomer (17) layer(Figure 4) which is able to penetrate between the parts (15, 16) in order to produce and anchoring phenomena, adhering to said parts and avoiding lateral dispersions (D) of combustible gas in the ceramic plate through the screen holes (12a) by stopping them. This keeps the burning zone restricted to the face (D1) in the surface of the ceramic plate (15).

The block comprising the flexible refractoryceramic plate and the thin ceramic housings (16) are fixed to the screen (12) by means of an elastomer layer (17) suited to high temperatures, complementing the sealing means of the irradiation modules (7) and producing a flexible joint which supports natural

vibrations which occur during the operation of the equipament and fit different materials possessing very thermal dilatation coeficients, i.e., the different ceramic materials and the metallic carcass.

One of this features of the refractory ceramic plate (15) is the flexible pores (see detail A in Figure 3), where the fiber positioning (F) kept ready to move (V), due to forced passage of gas (G); this free movement feature permits a dynamical distribution of the gas flow through the pores (R) of the fibrous structure, thus making the pores open and/or closed when necessary, depending on the use condition and keeping the balance between them. The gas volume flowing through the ceramic plate is able to be modulated and the emission power of the irradiation element is indirectly modulated by varying the combustible gas volume (G), but keeping active the discharge rate of the pores compatible to the combustion rate, therefore, the flame is stably positioned at the first layers (D1) of the flexible ceramic.

Other feature of the flexible ceramic (15) is that even under mechanical erosion the above mentioned properties are maitained, because the above described phenomena, which keeps the flame balance, occurs in the surroundings of the fire line, i.e., at the first 3mm to 5 mm deep of the flexible refractory ceramic plate. Erosion or removal of part of such surface material does not modify the flame balance which always occurs at the surface (D1) of the ceramic plate independently of the surface shape.

Another property of the ceramic plate associated to the flexibility feature and not affected by erosion, as stated above, is the ability of the irradiation element resist to dropping contamination, e.g., ink dorps in a continous painting process of paper. The drop material at the surface of the irradiation surface can be easily removed by mechanic procedures of scratching or abrasion avoiding other cleaning procedures and the system is quickly restored.

The bed (2) (Figures 1,2 and 8) as previously stated, is made of lower side metallic plates (LI) having angular flaps (18a), closing mirrors, blind mirror (EC) and instrument mirrors (EI) having holes suited to the devices to be fixed therein and botton caps (6) having side flaps (6a) e closing flaps (22 and P1); such side plates (LI) are alterned with counterventing channels (21) while the

botton caps (6) have one flap (22) at one side fixed by engaging to one of the LI flaps (18), and at the other side, the flap is fixed by means of screws (P1), therefore is provided one safety devide between the lower side plates (LI) and the bottom cap (6), the particular geometry feature of the caps permits that the flaps (18, 22) be easily unlocked offering an escape area for gases, in the case of internal explosion, the cap (6) is fixed to the structure by means of the screws (P1) for permitting the removal of the cap for maintenance ends.

Modular heat irradiation apparatus (1) is equiped with automatic lighting devices and monitoring means, which are interconnected to the LPC, not shown, such devices comprise the trigger (CT) and sensors of thermal flow (14), oxygen measuring means (23), and the UV sensor (Figure 13), better detailed ahead.

Automatic lighting system comprises the assembling of some trigger electrodes (CT). The lighting is produced by inonizing the air by using a high tension source which discharges over the bed (2). The triggers are mounted in a number which is enough for permit the lighting of the irradiation element even part of such triggers are disabled.

Thermal flow sensor (14), which position has been previously detailed, is the responsible for monitoring de heat flow inversion, since each sensor (14) monitores a maximum temperature differential between the median line (Y) of each ceramic plate (15) and the temperature of the feeding gas of the module, the verification occurs at the LPC for turn the equipment off when the differential is greater than maximum permitted limit, this would indicate thermal flow inversion, i.e., the flow is returning to the gas plenum and probably an explosio would occur. The thermal flow sensor is also used to indicate an erosion process in the ceramic plate and the replacement of such plate is necessary.

The Oxygen measuring means (23) (Figuras 10 and 11) employ, a sensor (26) based on Zirconium oxide, which is positioned in one device containing a temperature controlled chamber (26) (temperature control system not inidicated), and such device is formed by five tubular bodies (27, 28, 30, 31 and 33) welded (29) one to the other, the set (23) is fixed by a holder (34) positioned in the inner flap of the upper side (LS). An extension is fixed to the

tubular body (28) forming a venturi type system (30), the tube (30) having the greatest diameter conducts the sealing pressurized air inside the bed to outside. When the sealing air passes between the tube (30) and the broader section of the tube portion (31) it is accelerated in order to effect vacuum inside the portion (31) and in the body (28), providing a vacuum chamber, while the collector tube (33) conducts the smokes collected in the inner part of the chamber (28). The collection tip (35) is coupled to the upper portion of the tube (33) and holes and the concetrating flaps (37) are provided in the lower part (36) of such tip. The lighting system also employs the the tip (35) as ground contact for discharge the trigger.

The oxygen measuring means (23) is applied near to the burning zone, (D1) in order to continuous analyze the combustion of the irradiation element, optimizing the burning and controlling the amount of residual oxygen after the combustible burning. Such sensor is connected to the LPC of the monitoring system. Parameters of operation are adjusted in view of the desired application and the kind of combustible gas is used.

UV detector (24) (illustrated in Figure 1 and more detailed in Figures 12 and 13) can be double assembled, i.e., two flame detector (24) can be for each irradiation element (Figura 1), each detector has an UV sensor bulb which is commecially available and its respective encapsulating system (39) installed inside the cooling system (40) extending to collimation cavity of IR emission (CR) by a ceramic bulb (47) restricting and protecting the sight of the bulb and the sight field against obstructing clouds of vapor from the process or against UV emissions from other external sources. UV sensors (24) are positioned at the external side of the the instrument mirror (EI), more particularly fixed to the supports (44) which are fixed by tubes which are employed to conduct the pressurized sealing air inside the support tube fromthe irradiation element (4) to the cooling body (40).

Each set of UV detector (24) additionally comprise a cooling body (40) having ribs (41) at its external face in order to provide cooling channels for keep the internal housing chamber (42) of the sensors (38, 39) cool; such protection comprises a lower hole (43) which is coupled to the metallic box type support

(44) through which cooling air and connection wires of the electronic excitation and monitoring (called flame relay) are conducted.

The ceramic protector tube (47) is fixed to the cooling body (40) by the flange (45) which possesses inner tips as restraining means (46) of such tube (47).

A skilled person will see that the scope of the present invention is novel: irradiation modules, the monitoring performed by the sensors and measuring means via discrete electronic controls or LPC, the modular heat irradiator and its improved shape, a high efficiency of the heat transfer between the irradiating surface and the receiving substrate, the equipment designed for being easily adapted in any industrial process and all benefical effect achieved by this means which permit remarked improvements in the volatile removal from substrates, particularly wet removal from paper ou cellulose drying processes and the invention concept which permits a long term use of the equipment of the present invention and reducing maintenance interruptions.

Even the above mentioned invention be detailed for offer a better understanting, the same is not limited to the revealed applications or particular details presently revealed.

Other embodiments and variations of the present scope is intended as belonging to the present invention.